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ABSTRACT

The faculty of Dartmouth College was surveyed to measure the extent of instructional computing in undergraduate courses, including the total amount, the spread across the curriculum, and the variety of individual efforts. The on-campus teaching faculty received a short, four-question card asking if they had used computing in their courses. Those who said yes were subsequently interviewed by telephone. A total of 83 percent of the instructors (332/399) returned the questionnaire card, and 41 percent of these respondents mentioned the use of computing in a total of 184 courses. The telephone survey revealed that (1) computing is used in 12 percent of the sections of undergraduate courses; (2) the usage by discipline breaks roughly into 50 percent science, 35 percent social science, and 15 percent humanities; (3) computing takes a small amount of the average student's course time, but this varies widely for individual students; (4) one-quarter of the courses had no serious problems in using the computer, while about half were bothered by problems of individuals straining the limits of working equipment. Appendices include the questionnaire and telephone survey forms, as well as a breakdown of the data by departments and courses. (CMV)

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COMPUTING AS A MATTER OF COURSE

The Instructional Use of Computers at Dartmouth College

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Susan Hardy

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

John M. Nevison
Kiewit Computation Center
July 1976

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Introduction: Computing and Students

Computing is woven into the fabric of instruction at Dartmouth College and is an integral part of the academic environment. A 1975 survey showed that, during the 1974-75 school year, one quarter of the faculty and three quarters of the undergraduates took part in courses which used computing. This report summarizes that survey, which sees computing *through the eyes of the instructor*.

Before a discussion of the instructor's view of classroom computing, two aspects of the student's view bear mention: computer use over a four-year college career, and his or her ability to write a computer program. (Anyone who has written a computer program may be called *literate* in computing. *Literacy* in this sense should not be confused with *fluency*, which requires extensive work with computing.)

A student at Dartmouth will probably use the computer while at college. Ninety-three percent of the Class of 1975 have used the computer and the figure is already over ninety-six percent for the classes of 1976 and 1977. These usage figures could be deceptive. It is quite possible to play a game on a computer, or to do some research using another's program without ever writing a program of one's own.

Nevertheless, a Dartmouth student probably will write a computer program while at college. Seventy percent of the 1975 senior class enrolled in one of several elementary mathematics courses in which a student is required to write a computer program. Because there are other courses in which a student may have been required to write a program, the *computing literacy rate* among the graduating class *exceeded seventy percent*.

Details on the distribution of student usage have been discussed in earlier papers[1,2]. They showed that many students use tiny amounts of time and a few use enormous amounts of time. But, as the results of this study confirm, a little computing can carry a large idea. Those who use it a little may exhibit more finesse than those who use it a lot. The key to using a computer—much the same as using a library, buying a car, or even reading a report—is discrimination.

THE SURVEY

Purpose

During the Spring of 1975 the faculty of Dartmouth was surveyed to determine how undergraduate courses use computing. Every person who taught an on-campus course from the summer term of 1974 through the spring term of 1975 was included. The purpose of the survey was to measure the extent of instructional computing in undergraduate courses: the total amount, the spread across the curriculum, and the variety of individual efforts. The survey is a snapshot of one year's course use.

The faculty first received a short, four-question card asking if they had used computing in their courses. Those who said yes were subsequently interviewed by telephone. Eighty-three percent of the instructors (332/399) returned the questionnaire. Ninety-seven of the respondents used computing in a total of 184 courses.

Major Findings

The major findings are derived from the two levels of the survey. The preliminary, 332-card survey revealed that:

- Over one quarter (29%) of the responding faculty used computing in a course during the school year studied.
- 43% of the responding faculty have used computing at some time in their research.
- 45% of the responding faculty have written a computer program. So, by definition, the *computing literacy rate* at Dartmouth is 45% among the faculty. (And over 70% among the students—see discussion under Mathematics).

The 97 instructor/184 course telephone survey found that:

- Computing is used in 12% of the sections of undergraduate courses offered at Dartmouth.
- The usage by discipline breaks roughly into 50% science, 35% social science, and 15% humanities.
- Computing takes a small amount of the average student's course time, but can vary a lot from student to student.
- This use is important; more often "integral" to the course than "supplemental" or "incidental".

- The "most important benefit" of computing is to develop intuition and sharpen insight into the subject, that is, to *qualitatively* improve the course.
- One quarter of the courses had *no* serious problems in using the computer. About half were bothered by problems of individuals straining the limits of working equipment.

RESULTS

The next two sections detail the results of the 97-instructor/184-course telephone survey. The first section discusses the quantitative results, and the second section sketches a brief, department by department, picture of the varieties of usage. In this first section results are analyzed by question.

Results Analyzed by Question

What is a course?

Each instructor who used computing in a course was interviewed. The unit used to analyze responses was the instructor-course-term. That is, if an instructor taught Physics 3 once and Physics 43 once, his answers counted as two courses. If he taught a section of Physics 3 in the fall and another section in the winter, there were two sets of answers, two courses, for that course title, plus his section of Physics 43, for a total of three courses. (Only one instructor taught two sections of a single course in the same term and his answers were counted as a single course.) The 97 instructors who were interviewed taught 184 courses; the courses break down by division as follows:

Table 1. Responses by Academic Division

Percent	No. of Courses	Academic Division
12%	22	Humanities
36%	66	Social Sciences
52%	96	Sciences

Who uses computing?

As shown in Table 1, usage in science courses outnumbers that of the social sciences and humanities combined. The large departments in the sciences are Mathematics (36 courses), Physics (23) and Engineering (18); in social sciences, Geography (16), Sociology (16) and Psychology (14); in the humanities, Music (11).

Students in courses

Student use varies within as well as among classes. A great many uses of computing are small applications. If, when asked whether students wrote their own programs, an instructor said "some", the response counted as a "yes".

Many students use "canned" programs. Sometimes these programs are prepared by an instructor especially for the course. Other times a student makes use of a program in one of the many program libraries on the Dartmouth Time-Sharing System. Statistical and plotting programs are among those most frequently cited. In a large number of courses, students also write their own programs as well.

It is worthy of note that students do not spend a great amount of their course time on computing: for 42% of the responses, less than 10%. Yet, as one will see in the discussion below, this small use is of great significance.

Table 2. Students in Courses

Yes	
86%	Do your students ever run a canned program? (a program someone else wrote)
62%	Do they ever use any programs from the Kiewit public library?
64%	Do students in this course write programs of their own?

What percentage of a student's total course time is spent on computing each week?

Percent Response	Time Spent
42%	<10%
38%	10-30%
10%	40-60%
10%	70-100%

Course Enrollment

Percent Response	Course Size
44%	Small (1-15)
26%	Medium (16-30)
30%	Large (>30)

Course enrollment for those classes which used computing slightly favors the small class. The social sciences have an especially large number of these small courses.

Teachers in class

Most computing takes place outside the classroom. Homework assignments, term papers, and special projects all were cited by instructors when they described how their course used computing. Most instructors did not conduct classroom demonstrations, either because "we don't have the facilities" or because "response time was too bad during the middle of the day." Those who did give classroom demonstrations found that on-line work dramatizes a point and "makes ideas easier to understand."

Very few instructors utilized the PDQ service. This special, fast-response priority for class use had been available only since November 1974, and many were unaware of its existence.

Table 3. Classroom Demonstrations

Yes	
23%	Do you ever use the computer in classroom demonstrations?
5%	Have you ever used the special, fast-response (PDQ) service for these demonstrations? (asked of those who used the computer in class)

Equipment

In terms of computing equipment, most courses use the Dartmouth Time-Sharing System at Kiewit. Music, Astronomy, Psychology and Engineering courses make use of some minicomputers on campus. Geography, Astronomy, and Government use off-campus computers from time to time. Geography retrieves data from remote sensing satellites stored on a computer at Columbia. Astronomy ties into computers at Kitt Peak, Arizona. Government played a game on a machine at Santa Barbara.

Calculators, both desk and hand-held, are used in one-third of the courses; special terminals in one half. Most of the terminals that were called "special" are plotting terminals: either Tektronix scopes or x-y plotters. Sometimes the "special" terminal is a classroom unit that displays a demonstration on a television monitor.

Table 4. Equipment Use

Does the course use:

Yes	
96%	The Kiewit Computer?
6%	A minicomputer?
4%	Off-campus computers?
35%	Calculators?
50%	Special terminals?

Computing Services

Support from Computing Services is mostly beyond the pale of the course organization. Most instructors know when the class makes use of the DTSS program library. They are vaguely aware that students do obtain and read Computing Services publications but when asked if the course uses them, they say "no, not really, none were assigned". Thus, while only 35% of the instructors said that their students used Kiewit publications, a larger percentage of the students do in fact use them on their own. An instructor remains reluctant to think of a course of "using" these manuals because, unlike texts and reserve readings, they are rarely assigned in the course.

Very few instructors arrange with Computing Services for special user numbers for a course. Very few set up sublibraries specially for a course. (A great number do use some of the public sublibraries, such as PLOTLIB***.)

Table 5. Computing Services

Yes	
62%	Do they (students) ever use any programs from the DTSS public library?
35%	Does the course use any Kiewit publications?
10%	Were special numbers reserved for the course? (From Kiewit records)
6%	Were special sublibraries set up for the course? (From Kiewit records)

Effect and role of computing

The instructor uses computing because he believes it improves the quality of the course. In one case, an instructor stated that computing made the course worse because the Santa Barbara computer malfunctioned and delayed the international diplomacy

game being played by classes all over the country. The instructor was quick to observe that while these breakdowns detracted from the course, they did teach patience, "which is a virtue in diplomacy."

A very interesting result, especially in light of the small percentage of course time devoted to computing (see Table 1), is the importance instructors ascribe to the role of computing in the structure of the course. Fewer than 15% thought it was merely "incidental"; almost half thought it "integral."

Cross tabulation reveals that as the amount of course time devoted to computing increases, so does the likelihood that this use will be called "integral", and that its effect will be judged "much better".

Table 6. Evaluation (Part A)

How would you estimate the overall effect of computing on the quality of this course? Much better, better, worse, much worse?

Percent Response	Overall Effect
36%	Much better
54%	Better
1%	Worse
0%	Much worse
9%	Don't know/not applicable

How would you characterize the role of computing in the structure of the course? Integral, supplemental, incidental?

Percent Response	Role of Computing
47%	Integral
39%	Supplemental
14%	Incidental

Benefits

The instructional benefits of using a computer program can be viewed in a variety of ways. If it illustrates a concept in its structure or allows, through its use, a student to experiment with the ideas of the course, it may deepen his understanding of the subject. The program may enable the student to perform complex calculations such as numerical integration or matrix arithmetic. The same

program's biggest advantage might be that it performs those calculations on large amounts of data. All three of these benefits may accrue to the same program.

An instructor's "most important benefit" from working on a time-sharing system is often described with phrases like "experiment with", "concrete expression of theoretical concept", "test hypotheses", "play with", "develop ideas", "explore", "confront theory", "find out for yourself", "dramatize the reading". All such uses develop intuition and deepen insight into the subject.

Sometimes another aspect of computing is highlighted: the computer as a tool. Here the "benefit" is described as "computational aid", or "problem solver". The characteristic uses are complex—finding roots of equations, computing areas under curves, or calculating "real-world" engineering problems with nasty numbers. Not surprisingly, these uses are common in the sciences, especially Engineering and Physics.

A third outstanding benefit of a computer program is its use as a "data cruncher". In this case the emphasis is on the ability of the machine to manipulate large amounts of data. Phrases here include "data reduction", "manipulation", "handle". Of course the data are analyzed and examined, but the primary problem is how to deal with the volume of this raw information. Since the IMPRESS system was designed to handle precisely this problem, it is not surprising to find that the social sciences focus on data manipulation as the major benefit of computing.

If the subject being taught is computer science or computational methods, it too can be aided by allowing students to develop intuition through on-line work.

Altogether 82% (41 + 23 + 13 + 5) of the benefits of computing describe a qualitative change in the student's understanding of the subject matter of the course.

Table 7. Evaluation of Benefits (Part B)

What is the single most important benefit of computing in the course?

		Number of Courses (Percentage within Division)			
		College	Humanities	Social Sciences	Sciences
1.	Develop intuition and sharpen insight into subject.	75 (41%)	4 (18%)	30 (45%)	41 (43%)
2.	Enhance "realism" of the course through the solution of problems that are difficult or impossible to do by hand.	43 (23%)	0 (0%)	2 (3%)	41 (43%)
3.	Enhance "realism" of the course through the manipulation and analysis of large amounts of data.	24 (13%)	0 (0%)	20 (30%)	4 (4%)
4.	Speed up or develop through repetition the regular subject of the course.	25 (14%)	16 (73%)	7 (11%)	2 (2%)
5.	Teach computing, "the careful development of procedures".	9 (5%)	0 (0%)	1 (2%)	8 (8%)
6.	Other	8 (4%)	2 (9%)	6 (9%)	0 (0%)
	Total	184 (100%)	22 (100%)	66 (100%)	96 (100%)

In a few courses, where drill-and-practice predominates, the major benefit of computing is simply to accelerate the learning process and thus release class time for additional discussion of more important items.

Problems

The first rule of computing is that "machines break down." A number of pieces of sophisticated equipment must work reliably for a course to depend on computing and to schedule it as a regular activity. Perhaps the most surprising feature of Table 8 is that one quarter of the instructors, when asked for the "the most serious problem", responded "none", even after being reassured by the interviewer that if "problem" sounded too strong they could think "hassle."

But three quarters of the courses did encounter some kind of problem associated with computing. The source of these problems ranges from the central computer to the remote instructor. The first problem is severe. If the computer breaks down or if a terminal is in bad repair, no one can get anything done.

When the machinery is operating, two kinds of "population pressure" occur. First, there are a limited number of terminals on campus (350), and these vie for a limited number of ports (240). While the number of both ports and terminals at Dartmouth is large compared to that of most colleges, a large group of students, all trying to finish projects in the last few weeks of the term, can make gaining access to the computer difficult for some.

The second kind of "population pressure" is the slow response time after lots of users have succeeded in getting access to the computer. Delayed response (10-15 seconds) during the middle of the day is difficult to tolerate for an experienced user who remembers the instantaneous response of three years ago.

Using and writing programs bring the student and instructor face to face with the "bugs" in programs and the limits of computer languages. Such problems are irritating, but often of a user's own making. Many instructors claim responsibility for these problems.

A student fitting a line to a set of points can have two kinds of problems. He can understand the statistics but fail to be able to use the program—a computing problem—or, he can use the program but fail to understand the statistics—a course problem.

Table 8. Evaluation of Problems (Part C)

What is the most serious problem of computing in the course?

		Number of Courses (Percentage within Division)			
		College	Humanities	Social Sciences	Sciences
1.	None	45 (24%)	3 (14%)	16 (24%)	26 (27%)
2.	Equipment breakdowns	30 (16%)	10 (45%)	10 (15%)	10 (10%)
3.	"Getting on" ports and terminals	16 (9%)	2 (9%)	1 (2%)	13 (14%)
4.	Slow response time	26 (14%)	2 (9%)	8 (12%)	16 (17%)
5.	Program bugs, language inadequacies	22 (12%)	2 (9%)	11 (17%)	9 (9%)
6.	Student's computing problems	16 (9%)	0 (0%)	12 (18%)	4 (4%)
7.	Student's course problems	14 (8%)	2 (9%)	3 (5%)	9 (9%)
8.	Faculty course problems	11 (6%)	0 (0%)	3 (5%)	8 (8%)
9.	Other	4 (2%)	1 (5%)	2 (3%)	1 (1%)
	Total	184 (100%)	22 (100%)	66 (100%)	96 (100%)

Finally, some instructors confess that their own ignorance is a problem when dealing with new methods of analysis.

In summarizing Table 8, one can say that:

24% had no problems,
16% had machine problems,
46% had people-machine problems, and
14% had course problems.

Results Analyzed by Subject

Anthropology

Three different kinds of use appear in the department that studies the cultures of man. A cross-cultural analysis of data made possible by the IMPRESS-MECCA system is used in ethnography, both in an introductory and an advanced course. A class in folklore uses a computer program to analyze the themes in tales. A class in biological anthropology explores the idea of simulation through a few elementary programs demonstrating population processes.

Titles		
Anthropology	1	Introductory Anthropology
	24	Introduction to Biological Anthropology
	26	Ethnography
	54	Folklore

Economics

Economics students "get their hands dirty". When they use computing they write programs. In one elementary course, the class was troubled by the disparity in programming ability among the students. More advanced courses make use of computing to build and refine macroeconomic models, to estimate from the IMPRESS-Brookings data some equations for such models, to play with the finance and investment programs in TUCKLIB***, and to solve linear programming problems. In several courses term projects are often computer projects. Programming experience is a major benefit of computing. The students "do for themselves" and learn by doing.

Title		
Economics	12	Economics of the Stock Market
	21	Macroeconomics
	54	Macroeconomic Fluctuation and Growth
	62	Mathematical Economics

Education

One student examined IMPRESS school data as an independent study project.

Title		
Education	85	Independent Study in Education

Geography

The study of spatial distributions is enhanced by having a computer sift through large amounts of data looking for patterns. Eight courses use the computer to synthesize data and, often, to plot the results on a map. Sometimes the data originate from remote sensing devices such as earth satellites, sometimes they come from an IMPRESS county-city-state data base, and sometimes they come from the field work of the class itself. These analyses use multiple linear regression, factor analysis, and techniques available through IMPRESS to help reduce the data to significant spatial patterns.

In order to dramatize critical aspects of land use, several simulation games are played in these courses. RICEGROW*** is a game in which one person confronts the problems of a Southeast Asian rice farmer who tries to grow a good crop of rice. Students learned that using seeds of the new "green revolution" rice can make a difference. In one class, students "grew" an average of 20 crops per person (one student had 150 crops). *The Isolated State* involves many students playing different roles in an agricultural world of farming, wholesaling and retailing. Another multi-player game is ACRES. Using a given map (rural landscape, decaying city, model small town), land is developed with residents, industrialists and government officials all trying to cooperate with each other while making a personal profit. Needless to say, the many-player games teach both about the "system" and some elements of interpersonal and group dynamics.

A less interesting, but significant, use of computing in geography is the computer-as-secretary. Bibliographies for one course are maintained (and frequently revised) on-line. Data from field research are stored in the computer to provide a convenient file which is accessible to the whole class.

Titles		
Geography	1	Introduction to Human Geography
	10	Freshman Seminar in Geography
	11	Freshman Seminar in Geography: Viewpoints on the Third World
	15	Geography of Food and Hunger
	20	Spatial Analysis

25	Remote Sensing
28	Geographic Methods
29	Field Research
42	Introduction to Advanced Geographic Study
52	Urban Geography
53	Urban-Regional Simulation and Games
55	Agricultural Land Use and Agribusiness
82	Seminar in Remote Sensing

Government

Computing in the Government Department casts the computer in the role of versatile black box. The least mysterious of the box's functions is producing linear regressions on political data. The IMPRESS system is used by other courses to analyze election surveys and, while computing as the writing-of-programs remains invisible, computing as the analysis-of-survey-results becomes an integral part of the course. The black box also runs drill-and-practice programs on the theory of government, holds messages from student to instructor, and serves as a secretarial aid in the preparation of bibliographies.

A computer at the University of California at Santa Barbara served as the black box that mediated an international diplomatic game in which two International Politics classes participated.

Titles		
Government	7	International Politics
	34	American State Politics
	63	Politics and Economics of Government Budgeting
	70	Political Behaviour
	81	Public Opinion and Voting Behaviour: The 1972 Presidential Election
	83	Seminar in Politics and Economics of Government Budgeting
	96	Politics and Biology
	97	The Nature of Political Enquiry

History

One historian takes classes through IMPRESS data in search of answers to questions posed by two of his courses.

	Titles	
History	46	Urban History
	88	Comparative History of Black and White

Psychology

Psychology uses computing because it is a discipline that often uses a laboratory. Results of student experiments are regularly subjected to a variety of computer programs to do "descriptive and inferential statistics". Data collected in field work are often analyzed on the computer. Statistics students are "immersed in the computer". The experimental bent of the Psychology Department quite naturally pervades its course organization and its teaching. Some courses are broken into modules where the exams are on-line and the computer is the course clerk who tells a student how well he did, how far his average classmate has progressed, and what pace he should maintain to complete the term satisfactorily. Sometimes this clerk provides the syllabus of an advanced course or records the weekly quiz scores in an introductory course.

A course on cognition has developed interesting applications of computing used in several courses. Often an experiment is performed by having a machine display a group of characters on a television screen for a fraction of a second. As subjects of experiments, students try to discern some pattern in this group of characters. Because the machine administering these experiments is a computer, the student can also learn to design his own experiment. Teaching the design of experiments becomes faster and more flexible. Of course, the results of these experiments are analyzed on the computer.

	Titles	
Psychology	1	Introductory Psychology
	23	Social Psychology
	61	Experimental Study of Perception
	63	Experimental Study of Social Behavior
	68	Experimental Study of Cognition

81	The Teaching-Learning Process in the University
82	Environmental Psychology
87	Seminar in Pattern Recognition
89	Independent Research
101	(Graduate) Statistics in Psychology
103	Advanced Issues in Statistics and Design

Sociology and Math-Social Science

The heart of computing in Sociology is IMPRESS, an interactive program that allows a quick, analytical look at the results of a social survey. Because the student can look, then look a second time, he may explore ideas and confront his hypothesis with a wealth of concrete data.

Analysis of this kind is found in topics as diverse as the family, cross-cultural analysis, social networks and urban patterns. In a few courses students analyze data with their own computer programs. In others they design programs that simulate social systems.

Titles		
Sociology	5	Human Society
	7	Methods of Sociological Inquiry
	15	Technology, Work and Society
	31	Bureaucracy in Contemporay Society
	34	The Family as a Group and an Institution
	50	Urban Planning
	81	The Analysis of Continuous Social Science Data
	85	Reading Course in Cross Cultural Analysis
Math-Social Science	61	Analysis of Social Networks
	65	Data Analysis

Biology

The Biology Department uses computing only occasionally in its undergraduate course work. One course does complicated calculations of enzyme kinetics. One laboratory uses a program to interpret points from a polygraph. Several courses, however, use a model of simple genetic cross or of the estrous cycle to allow students to do otherwise "infeasible manipulations" of these systems. Some students use extensive computing in their independent projects.

	Titles	
Biology	5	Life Science
	35	Comparative Animal Physiology
	37	Endocrinology
	78	Biochemistry
	99	Seminar in General Biology

Chemistry

Several chemistry courses take advantage of the computer's ability to do complicated calculations quickly. Numerical integration and line fits of results help students get more out of labs. Theoretical demonstrations of titration curves, molecular orbitals and reactive collisions allow students to vary a program's parameters and develop a better understanding of the underlying theory.

	Titles	
Chemistry	4	General Chemistry
	5	General Chemistry
	6	General Chemistry
	71	Physical Chemistry I: Chemical Thermodynamics
	72	Physical Chemistry II: Chemical Dynamics
	153	Topics in Advanced Organic Chemistry

Environmental Science

When the pieces of an environmental system become cumbersome to juggle, they sometimes end up as a small model written in BASIC or DYNAMO. Population models illustrate what can happen when one varies a parameter. Often a student will turn to the computer for help with a term project.

Titles

Env. Studies	25	*Introduction to Modeling Environmental Systems*
	50	Environmental Policy Formation
	73	Human Population Dynamics

Engineering and Engineering Science

The department almost always uses computing "as a tool" and "as a matter of course" in everyday assignments of difficult problems: optimization theory, regression analysis, solution of systems of differential equations, circuit design, contour surfaces, frequency response analysis, and even "simulating a computer". It should be no surprise that one course asks each student to do two problems which "involve significant computer work". Another class requires projects showing familiarity with techniques: "one analytical, one experimental, and one computational". One student benefited from his honors project, which plotted acoustic radiation patterns, to better position his own stereo speakers.

Titles

Engineering	2	Surveying
Eng. Sciences	22	Systems I
Eng. Sciences	34	Principles of System Dynamics
Eng. Sciences	50	Distributed Systems and Fields
Eng. Sciences	51	Solid Mechanics
Eng. Sciences	52	Systems II
Eng. Sciences	57	The Application of Optimization to Environmental Management
Eng. Sciences	62	Fluid Dynamics
Eng. Sciences	68	Electronics II
Eng. Sciences	69	Computing Methods in Science and Engineering
Engineering	115	Urban Transportation
Engineering	121	Electronics III
Engineering	122	Semiconductor Theory Devices I
Eng. Sciences	41	Heat, Mass and Momentum Transfer
Engineering	56	Design and Analysis of Experiments
Eng. Sciences	60	Intermediate Fluid Dynamics
Engineering	62	Introduction to Two-Phase Flow
Eng. Sciences	99	Independent Study (Computing)

Geology

Geology uses computing to make complicated structures more comprehensible. A model of a many-layered marine clay or of an x-ray diffraction pattern of a shale sample makes the real world a little easier to handle. Large amounts of data are processed to generate telling maps.

	Titles	
Geology	3	Elementary Oceanography
	37	Marine Geology
	110	Geochemistry
	116	Tectonics

Mathematics

Computing frequently enters mathematics as the "concrete expression of theoretical concepts". When plotting is added to the course, a parameterized curve can be visualized. A simple computer program illustrates the idea of a limit, of a table of elementary functions, of a numerical integration, or of a technique in probability, statistics, or computer science. Often writing a program helps a student to "believe the mathematics" especially in an elementary course where a proof cannot be given. Sometimes a program can suggest "what is the theorem that we should try to prove".

Twelve of the thirty-six courses (not titles) used only the four-problem set that introduces computing to students. This set requires that after two lectures each student write four computer programs. Seventy percent of the graduating Class of 1975 completed the four programs. These programs are the only programs many students do. Other students write additional programs in other courses. (Instructors in physics and sociology courses that make regular use of computing have heard students remark that it was in these courses, and not in the mathematics four-problem set, that they felt they learned to program.)

	Titles	
Mathematics	2	Elementary Functions
	4	Calculus and Differential Equations
	5	Advanced Placement Calculus
	6	Introduction to Finite Mathematics

7	Introduction to Calculus: Honors Section
8	Calculus and Differential Equations: Honors Section
9	Advanced Placement Calculus: Honors Section
10	Elementary Statistics
13	Linear Algebra and Calculus of Several Variables
16	The Role of the Computer Outside the Sciences
17	Linear Algebra and Calculus of Several Variables: Honors Section
20	Discrete Probability
23	Functions of Several Variables
26	Introduction to Numerical Analysis
28	Introduction to Computer Science
36	Mathematical Models in the Social Sciences
40	Probability and Statistical Inference
43	Functions of a Complex Variable
48	Fundamentals of Systems Programming
58	Information Structures
69	Logic: Honors Section
88	Graph Theory

Physics and Astronomy

Behind the Physics Department's casual remarks about computing as "a problem solving tool" are a variety of applications that span the range from freshman explorations of Newton's laws of force through advanced undergraduate research projects. Students write programs to solve problems, analyze data, and model the behavior of physical systems (electrical or relativistic). Teachers use classroom demonstrations to illustrate hard-to-grasp theory with concrete examples. One class makes use of some simple drill-and-practice programs, another uses computer programs as part of the regular Keller-Plan units. One instructor's course "would not change at all" were he not to use a computer while another "would not teach without it".

Titles		
Astronomy	1	Cosmology
	45	Introduction to Astrophysics
	63	Galactic Structure and Dynamics
Physics	3	General Physics I
	4	General Physics II
	7	Freshman Seminar in Physics
	13	Introductory Physics I
	18	Advanced Placement Physics: Mechanics, Electricity and Magnetism
	19	Advanced Placement Physics: Waves, Modern Physics, Thermodynamics
	34	Modern Physics and the Construction of Reality
	41	Electricity and Magnetism I
	42	Electricity and Magnetism II
	44	Mechanics
	65	Methods of Theoretical Physics
	66	Optics
	69	Thermodynamics
	71	Quantum Mechanics I
	73	Solid State Physics I
	76	Advanced Laboratory
	85	Special Topics in Physics
	114	General Relativity and Cosmology

Humanities

Computing is infrequent, but when used, its application is unusual and interesting in the humanities. An art course in basic design finds that a student who uses computing in a project will better grasp the idea that "design is taking a simple idea and through repetition, creating something organic, complex".

In German and Latin, drill-and-practice routines are available for voluntary student use. Both a course on Cicero and a course on Greek Archaeology use the computer as a class scribe that provides up-to-date bibliographies for students on a moment's notice. The 25 bibliographies in archaeology are organized around 25 sites and provide references to the most recent journals.

Music has developed several uses of computing. An on-line ear-training system helps the beginner listen better. Elementary composition is also done on-line with an interactive system that lets a student write a piece, listen to it, and revise and repeat the process until he is happy with his result. Recently a library of sounds from musical instruments and other sources plus a more powerful set of commands has allowed an advanced composer of electronic music to compose and revise in much the same fashion as the beginning student.

The Philosophy Department (and recently also the Math Department) lets students try their hand at proving theorems with an interactive system called BERTIE (after Bertrand Russell). Because it allows the student to learn on his own, the system is especially suited to the needs of the very popular Keller-Plan course on Logic and Language.

Titles		
Art	10	Basic Design
German	1	German
Greek and Roman Studies	53	Greek Archaeology: Classical and Hellenistic
Latin	1	Introductory Latin
	20	Cicero
Music	3	Listening, Composing, Performing
	6	Introduction to Music Theory
	36	Theory I
	46	Theory II
	55	Introduction to the Composition of Electronic Music
	56	Theory III
Philosophy	10	Logic and Language

CONCLUSION

The use of computing is analogous to that of the library: all are free to use the service and the frequency of this use varies widely between courses and between students within a given course. A small computer program, like a critical reference in the library, will sometimes be the key that unlocks a complicated idea. "Computing" can be an analytical method, a data manipulation or a creative exploration. On an interactive time-sharing system one can question and probe with a computer. Frequently this give-and-take not only broadens, but deepens, what a student can learn. The instructor senses this qualitative change and makes computing an integral part of his course.

In short, computing at Dartmouth has matured to the point where it is "no big deal" but to do without it would be "unthinkable."

Appendix A

Coverage

Initial Postcard Survey

Computing Services and Instructional Services are trying to find out a few things about courses at Dartmouth.

1. Did you use computing in any of the courses you taught in the last year?

   ____ Yes: when could we call you? _____

   ____ No: why not? _____

2. Do you use computing in your research?

   ____ Yes ____ No

3. Have you ever written a computer program?

   ____ Yes ____ No

4. Have you used slides, movies or television in any of your courses in the last year?

   ____ Yes ____ No

Thank you for your help. Please drop this card in the inter-campus mail.

Follow-up Survey of Computing in Courses

Teacher Name _____
Course Name _____

Hello, this is _____ over at Kiewit. We are taking a survey of the uses of computing in courses. Do you have a few minutes to talk now? [When would it be convenient for me to call back?]

You indicated on the postcard you returned that you have used computing in your courses last year. Which ones? [Start a sheet for each course.]

[Do you use computing in any of the courses you have taught in the past year (Spring 1974 through Spring 1975)?] ____ yes; which ones?; start sheets ____ no; go to card and finish.

1. Teacher Code: _____
2. Course Code: _____

Can you summarize in a few words how _____ uses computing? [If you have taught it twice, has this use varied?]

To make sure we don't overlook something, I have some short-answer questions about the course. First, your students' use of computing.

3. Do your students ever run a canned program? (a program someone else wrote)
   ____ Yes ____ No
4. Do they ever use any programs from the DTSS public library?
   ____ Yes ____ No
5. Do students in this course write programs of their own?
   ____ Yes ____ No
6. What percentage of a student's total course time is spent on computing each week? (to the nearest ten percent) ____ %

Now turning to how you have used computing in teaching this course . . .

7. Do you ever use the computer in classroom demonstrations?
   ____ Yes ____ No (on to 9)
8. Have you ever used the special, fast-response (PDQ) service for these demonstrations?
   ____ Yes ____ No ____ Don't Know/Not Applicable
9. What is the single most important benefit of computing in the course?
10. What is the most serious problem of computing in the course?
11. How would you estimate the overall effect of computing on the quality of this course; does it make the course:
    ____ Much Better ____ Better ____ Worse
    ____ Much Worse ____ Don't Know/Not Applicable
12. How would you characterize the role of computing in the structure of the course: is it integral, supplemental, or incidental?
    ____ Integral ____ Supplemental ____ Incidental

Now, a few quick questions about the kinds of equipment and services your course may use.

13. Does the course use the Kiewit computer?
    ____ No ____ Yes
14. [Does the course use] a minicomputer?
    ____ No ____ Yes; which one? _____
15. [Does the course use] off-campus computers?
    ____ No ____ Yes; which one? _____
16. [Does the course use] calculators? (desk or hand-held calculators)
    ____ No ____ Yes
17. [Does the course use] any special terminals?
    ____ No ____ Yes; which one? _____

18. [Does the course use] any Kiewit publications?
    ____ No ____ Yes; which ones? _____

19. Are there any other aspects of computing in the course that we have missed? _____

(You said you are also using computing in _____); [Go to B on a new sheet.]

Finally, do you know any other members of your department we should be sure to talk to? _____

_____

20. Enrollment:

21. Term: ____ S74 ____ X74 ____ F74 ____ W75 ____ S75

22. Special Numbers: ____ No ____ Yes; which? _____

23. Sublibrary: ____ No ____ Yes; which? _____

_____

Interviewer's Impressions:

Appendix A

Table A-1. Coverage

	College Total	Cover-age	Survey Total	Used Computing
1. Faculty	399	83%	332	97 (29%)
2. Courses	1,632	89%	1,456	184 (13%)
3. Student-Course-Terms	34,833	92%	32,212	5,981 (18%)

Coverage

The survey included 83% (332) of the instructors who taught 89% (1,456) of the courses with 92% (32,212) of the enrollment for the four terms. (The results are biased slightly against the part-time instructor who is not currently a member of the faculty and who taught a special course with a smaller than average enrollment.)

A course is defined here as one faculty member teaching one course (or one section of a large course) for one term. Student-course-terms are commonly called enrollment. The 18% enrollment involved 73% of the undergraduates.

Table A-2 shows who did not respond to the survey. This breakdown should convince even the most skeptical that the survey figures are subject to error more from indecision among those 332 who did respond ("Did that optional assignment constitute use of my course?") than to error from insufficient responses.

Coverage by Department

Of the 399 people who were eligible to be included in the survey, 332 responded and 67 did not. One can see that those who failed to respond probably did not use much computing. While this argument implies that the survey estimate of overall use might be a shade optimistic, it also implies that the list of the 184 courses identified as using the computer may be an exhaustive, that is, *complete* list. So the no-responses imply that while about 29% (maybe less) of the faculty used the computer, at least 73% of the students (and maybe more) used it. Remember that the student estimate comes from comparing student records with the 184-course list and that if the "no responses" all spoke up, they could only make the list longer and increase the number of students reached.

Listed below, by department, are those who did not respond. Also included is the response to the first question on the card: "Did you use computing in any of the courses you taught in the last year?"

Table A-2. Number of Responses By Department

Department	Yes	No	No Response
Anthropology	3	5	0
Art	2	11	4
Biology	4	9	8
Black Studies	0	3	0
Chemistry	5	10	2
Chinese	0	2	0
Classics	1	7	1
Comparative Literature	0	18	1
Drama	0	12	2
Earth Sciences	2	4	2
Economics	3	11	2
Education	1	2	2
Engineering	14	6	2
English	0	23	10
Environmental Studies	2	2	2
Geography	5	3	1
German	2	4	1
Government	5	11	0
History	1	18	0
Mathematics	20	9	3
Music	3	6	5
Native American Studies	0	0	1
Philosophy	3	6	0
Physics & Astronomy	10	4	0
Psychology	6	11	2
Religion	0	5	3
Romance Languages	0	13	3
Russian Languages	0	3	0
Sociology	5	5	0
Other	0	12	10
TOTAL	97	235	67

Appendix B

The Maturing World of Computing:
Comparison of Course Titles from 1968 to 1975

The 1975 survey was the second taken to determine the extent of instructional computing at Dartmouth. In 1968 William E. Slesnick surveyed Dartmouth faculty members by letter to find out who had used course-related computing and what users had done. The responses to this letter were described in his report, *Educational Uses of the Computer at Dartmouth College* (Kiewit Computation Center, Dartmouth College, 1968). The two surveys are significantly different in methodology and coverage; comparisons between the two should be carefully made and cautiously accepted.

The two surveys are not strictly comparable because the Slesnick study asked for *any* past uses of instructional computing and the Nevison survey covered only courses offered during a single academic year. Moreover, the Slesnick report gives no evidence of having reached the 83% coverage achieved by the 1975 survey. Thus the Slesnick report's list of course titles may well be incomplete.

In fact the list of course titles reported by Slesnick is shorter than the list of computer-related courses taught in 1974-75; the Slesnick report lists 86 titles while Nevison refers to 147. Some of the difference is attributable to the growth of instructional computing at Dartmouth; however, in comparing the two lists, one is struck by both the constancy of some of the uses and by the state of flux characterizing courses in general. New courses are constantly being devised and others discarded; courses that use computing are no exception.

Sudden growth or precipitous decline in departmental use is sometimes the result of the arrival or departure of a single instructor. In many departments the use of computing depends on the interest of a few people, just as the teaching of statistics generally falls on the shoulders of the few "quantitative" specialists.

Some departments seem to have early realized the possibilities of computing in their disciplines and have added few new applications in recent years. Among such departments are Chemistry, Education, Economics and Sociology.

Usage in some departments has grown, either because a new idea has spread through the department, or because someone has imported a new way of approaching a traditional subject. Biology, Government, Mathematics, Physics and Psychology appear to fit this mold.

A quantum leap, from no computing to some computing, has occurred in several departments: Art, Music, History, German, Philosophy, Environmental Science, Math-Social Science, and Anthropology. Courses in Environmental Science and Math-Social Science, along with a number of new courses in Engineering, seem to have resulted in part from the new interest in systems modeling that the computer has made possible.

An unforeseen expansion has occurred in the Department of Geography. Threatened with the tidal wave of data from the remote sensing satellites, the geographers have turned to the computer to sift this information for useful patterns. Even after the data are understood, the computer remains indispensable for data manipulation.

Of course, a few uses have died. For example, the Romance Languages Department no longer uses any of the drill-and-practice routines in Spanish.

In summary, the two lists of course titles chronicle a dynamic and maturing use of computing throughout the wide spectrum of courses offered at a liberal arts college.

Slesnick 1968

Biological Sciences

Introduction to Biology 1 & 2
Genetics 38
Aquatic Ecology 77

Chemistry

General Chemistry 3
Physical Chemistry 72
Molecular Structure & Bonding 81
Undergraduate Investigation in Chemistry 87

Nevison 1975

Art

Basic Design 10

Anthropology

Introduction to Anthropology I
Introduction to Biological Anthropology 24
Ethnography 26
Folklore 54

Biology

Life Science 5
Comparative Animal Physiology 35
Endocrinology 34
Biochemistry 78
Seminar in General Biology 99

Chemistry

General Chemistry 4
General Chemistry 5
General Chemistry 6
Physical Chemistry I: Chemical Thermodynamics 71
Physical Chemistry II: Chemical Dynamics 72
Topics in Advanced Organic Chemistry 153

Classics

Introduction to Latin 1
Readings in Latin Poetry 3
Seminar in Greek Mathematics 5
Seminar in Cato the Elder 80

Earth Sciences

Geomorphology 33
Hydrology 36
Geophysics 110
Project Research 137
Thesis Research 157

Economics

Introduction to Statistics 22
Money & Banking 26
Economic Risk & the Corporation 55
Econometrics 72
Readings in Economics 85
Senior Thesis 87

Education

Principles of Education 41
Introduction to Teaching 43
Practice Teaching 44

Classics

Greek Archaeology: Classical & Hellenistic 53
Latin 1
Cicero 20

Geology (Earth Sciences)

Elementary Oceanography 3
Marine Geology 37
Geochemistry 110
Tectonics 116

Economics

Economics of the Stock Market 12
Macroeconomics 21
Macroeconomic Fluctuation & Growth 54
Mathematical Economics 62

Education

Independent Study in Education 85

Engineering Sciences

Introduction to Engineering 21
Elementary Statics and Dynamics in Engineering 22
Solid Mechanics 51
Introduction to Linear Systems 52
Active & Nonlinear Circuits 64
Intermediate Thermodynamics 65
Computational Methods in Engineering & Sciences 69
Electricity & Magnetism 71
Undergraduate Investigations in Engineering 87
Honors Seminar 88

Engineering Sciences

Surveying 2
Systems I 22
Principles of Systems Dynamics 34
Distributed Systems & Fields 50
Solid Mechanics 51
Systems II 52
The Application of Optimization to Environmental Management 57
Fluid Dynamics 62
Electronics II 68
Computing Methods in Science & Engineering 69
Electronics III 121
Urban Transportation 115
Semiconductor Theory Devices I 122
Heat, Mass and Momentum Transfer 141
Design and Analysis of Experiments 156
Intermediate Fluid Dynamics 160
Introduction to Two-Phase Flow 162
Independent Study (Computing) 199

Geography

Introductory Human & Economic Geography 1
Physical Geography 22
Introduction to Advanced Geographic Study 42
Thesis Course 87

Environmental Science

Introduction to Modeling Environmental Systems 25
Environmental Policy Formation 50
Human Population Dynamics 73

Geography

Introduction to Human Geography 1
Freshman Seminar in Geography 10
Freshman Seminar in Geography: Viewpoints on the Third World 11
Geography of Food and Hunger 15
Spatial Analysis 20
Remote Sensing 25
Geographic Methods 28
Field Research 29
Introduction to Advanced Geographic Study 42
Urban Geography 52
Urban-Regional Simulation & Games 53
Agricultural Land Use & Agribusiness 55
Seminar in Remote Sensing 82

German

German 1

Government

American Parties & Politics 33
Congress & the American Political System 34
Political Behavior 50

Mathematics

Calculus & Differential Equations 4
Calculus for Advanced Placement Freshmen 5
Introduction to Finite Mathematics 6
Calculus & Differential Equations: Honors Section 8
Calculus for Advanced Placement Freshmen: Honors Section 9

Government

International Politics 7
American State Politics 34
Politics & Economics of Government Budgeting 63
Political Behavior 70
Public Opinion & Voting Behavior—The 1972 Presidential Election 81
Seminar in Politics & Economics of Government Budgeting 83
Politics and Biology 96
The Nature of Political Enquiry 97

History

Urban History 46
Comparative History of Black & White 88

Mathematics

Elementary Functions 2
Calculus & Differential Equations 4
Advanced Placement Calculus 5
Introduction to Finite Mathematics 6
Introduction to Calculus: Honors Section 7
Calculus & Differential Equations: Honors Section 8

The Role of the Computer Outside the Sciences 16
Elementary Statistics 20
Advanced Techniques of the Calculus 33
Mathematical Models in the Social Sciences 36
Logic 39
Applied Linear Algebra 41
Mathematical Statistics 50
Honors Probability 60
Honors Number Theory 75
Seminar in Probability 80
Theory in Computing 88

39

Advanced Placement Calculus: Honors Section 9
Elementary Statistics 10
Linear Algebra & Calculus of Several Variables 13
The Role of the Computer Outside the Sciences 16
Linear Algebra & Calculus of Several Variables: Honors Section 17
Discrete Probability 20
Functions of Several Variables 23
Introduction to Numerical Analysis 26
Introduction to Computer Science 28
Mathematical Models in the Social Sciences 36
Probability and Statistical Inference 40
Functions of a Complex Variable 43
Fundamentals of Systems Programming 48
Information Structures 58
Logic: Honors Section 69
Graph Theory 88

Mathematics-Social Sciences

Analysis of Social Networks 61
Data Analysis 65

Appendix B

Physics and Astronomy

General Physics 3
Classical Physics 14
Contemporary Physics 23
Contemporary Physics 24
Electricity & Magnetism 42
Advanced Laboratory 76
(A) Evolution of the Universe 2

Music

Listening, Composing, Performing 3
Introduction to Music Theory 6
Theory I 36
Theory II 46
Introduction to the Composition of Electronic Music 55
Theory III 56

Philosophy

Logic and Language 10

Physics and Astronomy

(A) Cosmology 1
(A) Introduction to Astrophysics 45
(A) Galactic Structure & Dynamics 63
General Physics I 3
General Physics II 4
Freshman Seminar in Physics 7
Introductory Physics I 13
Advanced Placement Physics: Mechanics, Electricity & Magnetism 18
Advanced Placement Physics: Waves, Modern Physics, Thermodynamics 19
Modern Physics & the Construction of Reality 34

Psychology

Psychological Principles Applied to Organizations 22
Statistics & Experimental Design in Psychology 30
Experimental Analysis of Behavior 61,62,63
Mathematical Psychology 81

Electricity & Magnetism I 41
Electricity & Magnetism II 42
Mechanics 44
Methods of Theoretical Physics 65
Optics 66
Thermodynamics 69
Quantum Mechanics I 71
Solid State Physics I 73
Advanced Laboratory 76
Special Topics in Physics 85
General Relativity & Cosmology 114

Psychology

Introductory Psychology 1
Social Psychology 23
Experimental Study of Perception 61
Experimental Study of Social Behavior 63
Experimental Study of Cognition 68
The Teaching-Learning Process in the University 81
Environmental Psychology 82
Seminar in Pattern Recognition 87
Independent Research 89
(Graduate) Statistics in Psychology 101
Advanced Issues in Statistics & Design 103

Romance Languages

Introductory Spanish 1
Introductory Spanish 4

Sociology

An Introduction to Human Society 1
Population Problems 30
Comparative Social Institutions 32
Social Stratification 35
Sociology of Education 38
Social Maladjustment 48
Methods of Sociological Investigation 62,63
Computer Simulation of Social Processes 80
Futurism 81

Sociology

Human Society 5
Methods of Sociological Inquiry 7
Technology, Work & Society 15
Bureaucracy in Contemporary Society 31
The Family as a Group & an Institution 34
Urban Planning 50
The Analysis of Continuous Social Data 81
Reading Course in Cross Cultural Analysis 85

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